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INTERACTION OF CARDIORESPIRATORY PHYSICAL FITNESS AND HEAT TOLE--ETC(U)
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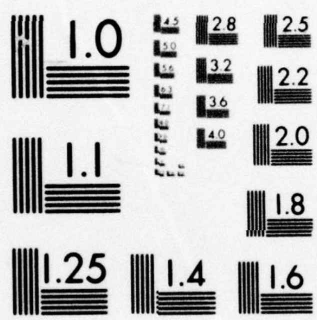

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INTERACTION OF CARDIORESPIRATORY PHYSICAL FITNESS AND HEAT TOLERANCE

by

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Contents

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1.0 Introduction

The importance of physical training and/or cardiorespiratory physical fitness on physiological responses to work in the heat, rate of heat acclimatization and retention of acclimatization has been a controversial subject for the past twelve years. During the initial eight years of this time period, Piwonka et al. (8), Piwonka and Robinson (7) and Gisolfi and Robinson (2) indicated that the physiological adjustments to heat were substantially better in physically trained individuals while Strydom et al. (15), Strydom and Williams (14) and Greenleaf et al. (3) disagreed. The majority of the more recent studies add further support to the improved physical performance in the heat and greater heat tolerance associated with increased levels of physical fitness (1, 4, 5, 6, 9, 12). However, the findings of some reports still cast some doubt (11, 13). The interpretation of these studies confirming or refuting an advantageous effect of physical fitness on human performance of work in warm climates could have important consequences in the planning of future military operations in the tropical and desert areas of the world.

The primary purpose of this paper is to evaluate the earlier literature (1965-1972) and to a greater extent the more recent experimental literature (1973-1977) concerning the relationship between physical fitness and work performance in the heat, rate of heat acclimatization and retention of acclimatization, and present a single comprehensive report. The experimental findings from our Institute concerning this topic are described in some detail.

2.0 Approach

2.1 Earlier Experimental Literature (1965-1972).

Table 1. Early experimental literature discussing the relationship between physical training and/or cardiorespiratory physical fitness and heat tolerance while performing physical work.

Importance of Training and Fitness	
Supports	**Disputes**
Piwonka et al., 1965 (8)	Strydom et al., 1966 (15)
Piwonka and Robinson, 1967 (7)	Strydom and Williams, 1969 (14)
Gisolfi and Robinson, 1969 (2)	Greenleaf et al., 1972 (3)

The early experimental literature which contributes original research findings supporting or disputing the relationship between physical fitness and work performance in the heat is summarized in Table 1. The impact of each of these investigations on the understanding of this topic is evaluated in the next major section (Results and Discussion).

2.2 Recent Experimental Literature (1973-1977).

In 1973 a review article was published by Wyndham (17) which discussed the existing dispute concerning the present topic. While this article presented no

additional original research findings, it seemed to stimulate a resurgence of interest to further evaluate this research problem. Although the earlier literature was pioneering in many ways, it was also experimentally descriptive while the more recent literature generally concerns the elucidation of mechanisms to explain findings. The more recent experimental findings (1973-1977) concerning this topic are presented in Table 2. The relevant information provided by this literature is also evaluated in the next section.

Table 2. Recent experimental literature discussing the interaction of physical training and/or cardiorespiratory physical fitness and heat tolerance during physical work.

Importance of Training and Fitness	
Supports	Disputes
Gisolfi, 1973 (1)	Shvartz et al., 1973 (11)
Nadel et al., 1974 (5)	Shvartz et al., 1975 (13)
Pandolf et al., 1977 (6)	
Roberts, et al., 1977 (9)	
Shvartz et al., 1977 (12)	
Henane et al., 1977 (4)	

2.3 Retention of Work-Heat Tolerance.

A thorough understanding of the relative importance of physical training and/or physical fitness on work-heat tolerance and heat acclimatization is of obvious practical importance to the armed forces. Retention of the physiological benefits associated with heat acclimatization or improved work-heat tolerance may also be related to physical fitness level. Retention of these benefits becomes increasingly important when one considers the deployment of armed forces and operational efficiency. While Williams et al. (16) reported high percentage losses of heat acclimatization after three weeks in cool conditions (nearly 100% for heart rate and 50% for rectal temperature), Pandolf et al. (6) showed small insignificant losses of these same physiological variables for a comparable time period; these apparent differences are possibly explained by the cardiorespiratory fitness levels of these subjects.

3.0 Results and Discussion

The cardiovascular and thermoregulatory adaptations to physical training and to heat acclimatization have been studied extensively, and the documentation has been recently summarized (10, 17). The classic description of the heat acclimatized individual performing work in the heat denotes the maintenance of a high level of sweating, lowered heart rate (HR), and lowered internal body temperature. However, many of these same physiological adaptations are associated with the physical training process. The question of whether these comparative adaptations are both qualitatively and quantitatively similar has sparked a research controversy which continues into this period of review.

3.1 Early Observations.

In 1965, Piwonka et al. (8) reported the performance of 5 competitive distance runners and 7 untrained subjects while walking on a treadmill at 5.6 km/hr (5.6% grade) for 85 min in dry heat (40°C db, 23.5°C wb). The HR and rectal temperature (T_{re}) responses for the runners plateaued in the heat at average values of 118 bts/min and 38.2°C, respectively, while the untrained subjects' responses continuously rose and reached values of 173 bts/min (HR) and 39.5°C (T_{re}). The overall sweat rate was lower for runners but 2.4 times greater per °C rise of T_{re} when compared to the untrained subjects. These authors concluded that their runners "behaved as though they were acclimatized to the heat".

During the following year, Strydom et al. (15) reported findings from 5 relatively unfit mine laborers exposed to humid heat (36.1°C db, 33.9°C wb) for five hours while stepping on and off a 30.5 cm bench before and after a mild physical training program. The training stimulus utilized involved mild exercise (oxygen uptake ≈ 0.8 - 1.0 L/min) for 12 days (5 hours/day) in a "cool" environment. After physical training, the first hour HR and T_{re} group average responses in the heat (HR = 143 bts/min, T_{re} = 38.3°C) compared favorably to the first-hour responses of acclimatized subjects (HR = 134 bts/min, T_{re} = 38.3°C). However, the fifth-hour responses were markedly lower for the acclimatized subjects (HR = 132 bts/min, T_{re} = 38.9°C) compared to the two remaining subjects who had undergone training (HR = 181 bts/min, T_{re} = 39.8°C). Strydom et al. (15) concluded "that although training may improve performance under conditions of heat, it certainly cannot replace acclimatization". Furthermore, these authors stated that the conclusions from the study by Piwonka et al. (8) were "invalid" because the higher maximal oxygen uptake ($\dot{V}O_2$ max) values of the runners gave them an advantage compared to the untrained at the same absolute work load in the heat.

In their next study, Piwonka and Robinson (7) evaluated the performance of 4 of the 5 runners from their previous investigation (8) at the same work level but in a more intense dry heat (50°C db, 28°C wb). The runners displayed rapid improvement (lowering) of HR and T_{re} during the four-day exposure while sweat rate increased by an average of 11% (range, 2.5 - 21%). These authors concluded that "the intensive training program of the runners completely conditioned them for work in moderate heat (40°C db, 23.5°C wb), and it apparently improved their capacities for acclimatization to a severe heat stress (50°C db, 28°C wb)".

In 1969, Gisolfi and Robinson (2) studied the effects of intensive interval training (1 hour daily, 5 times/week) on tolerance for work in the heat (50°C db, 27°C wb) for 5 initially untrained men. The work in the heat consisted of 90 min of treadmill walking (5.6 km/hr) using either a 2.5 or 5.6% grade. After training, the physiological responses to heat stress were reduced (HR = 141 bts/min, T_{re} = 38.7°C) from pre-training values (HR = 168 bts/min, T_{re} = 39.6°C) while average sweat rate per °C rise in T_{re} (above 37°C) increased about 50%. However, the comparable physiological responses of the competitive distance runners were shown to be superior to these "trained" men. These authors stated that "interval training indoors improved the heat tolerance of the men significantly, but did not fully acclimatize them for work in the heat".

Piwonka and Robinson (7) suggested that the low exercise intensity for training utilized by Strydom et al. (15) may have negated any significant improvement in heat tolerance. Accordingly, in their next study Strydom and Williams (14) had 23 young Bantu men train four times each day for 12 days to moderate work ($\dot{V}O_2$ ≈ 1.5-1.6 L/min) and evaluated their performance to a four hour standard heat tolerance test (33.9°C db, 32.2°C wb). When exposed to the heat after training, physiological responses (HR, T_{re} and sweat rate) were significantly improved for the 1st and 2nd hours only. These authors conceded "that the men after such training could be classified as being partially acclimatized to heat", but they questioned the adequacy of a two-hour heat exposure for evaluating the true extent of acclimatization.

Greenleaf et al. (3) evaluated the performance of 7 young men ($\dot{V}O_2$ max range, 42-66 ml/kg•min) during three 2-hour heat acclimatization exposures (47.7°C db, 32.7°C wb) on a bicycle ergometer at a relative $\dot{V}O_2$ of 28 ± 1%. Their results showed no positive relationship between $\dot{V}O_2$ max and tolerance to heat while working at the same relative work intensity despite large differences in sweating.

Most of these authors agree that physical training in cool conditions improves tolerance to work in the heat but the extent or degree of improvement remains controversial. Even those authors (14, 15) who question the relationship between physical training and the true extent of acclimatization show that training does improve heat tolerance. The main debate appears to involve the length of the exposure duration in the heat; exposure durations of less than two hours compared to greater than two hours. The major benefits associated with physical training appear to involve the former (< 2 hour exposure) rather than the later (> 2 hour exposure) duration. Thus, physical training appears to improve the initial circulatory responses to work in the heat but cannot totally replace the acclimatization process.

The training related observations show that strenuous interval training is superior to moderate continuous exercise which in turn is superior to mild continuous exercise for improving performance in the heat. As expected, training at intensities greater than 50% of $\dot{V}O_2$ max appear more beneficial for increasing performance. When physically trained men are compared to untrained, the trained appear to have an advantage at the same absolute work intensity, but not necessarily at the same relative intensity.

These heat and training related observations (Table 3) as summarized from the early literature are of some consequence and practical importance to the armed forces. The beneficial effects of physical training for the deployment of troops (> 2 hour exposure periods) in hot areas can be questioned. The observations concerning the type and intensity of training for optimal gains can be used in the planning guidelines by the armed forces. Since troops are more apt to be functioning at the same absolute rather than relative work load, the advantage given trained individuals should be of significant importance.

Table 3. Major effects of endurance training or physical fitness on heat tolerance from early experimental observations.

Heat tolerance or acclimatization	Performance Increase	Performance Decrease	Performance No Effect	References
Heat Related				
Exposure duration				
- < 2 hrs	X		?	Piwonka et al., 1965; Strydom et al., 1966; Piwonka & Robinson, 1967; Gisolfi & Robinson, 1969; Strydom & Williams, 1969.
- > 2 hrs			X	Strydom et al., 1966; Strydom & Williams, 1969.
Heat stress level				
- intense heat	?		?	Piwonka & Robinson, 1967; Gisolfi & Robinson, 1969.
- moderate heat	X		?	Piwonka et al., 1965; Strydom et al., 1966; Strydom & Williams, 1969.
Training Related				
Type of training				
- strenuous interval training	X		?	Piwonka et al., 1965; Piwonka & Robinson, 1967; Gisolfi & Robinson, 1969.
- mild continuous training			?	Strydom et al., 1966
- moderate continuous training	X		?	Strydom & Williams, 1969.
Training intensity				
- < 50% $\dot{V}O_2$ max			?	Strydom et al., 1966.
- > 50% $\dot{V}O_2$ max	X		?	Piwonka et al., 1965; Piwonka & Robinson, 1967; Gisolfi & Robinson, 1969; Strydom & Williams, 1969.
Comparative work load				
- same absolute work load	X		?	Piwonka et al., 1965; Strydom et al., 1966; Piwonka & Robinson, 1967; Gisolfi & Robinson, 1969; Strydom & Williams, 1969.
- same relative work load			X	Greenleaf et al., 1972.
Type of subject				
- trained competitive athletes	X		?	Piwonka et al., 1965; Piwonka & Robinson, 1967.
- untrained	?		?	Strydom et al., 1966; Gisolfi & Robinson, 1969; Strydom & Williams, 1969.

3.2 Recent Observations.

The review article by Wyndham (17) in 1973, which discusses the dispute concerning this topic also serves as a reference point to an era of increasing interest amongst investigators for more definite research to evaluate mechanisms for explaining their findings. In 1973, Shvartz et al. (11) evaluated the performance to a work-heat test (50°C db, 28°C wb, 5.6 km/hr, 5% grade) after three programs of acclimatization (dry heat, wet heat of equal stress, exercise at 23°C). Each acclimatization program was 60-90 min/day for six consecutive days; mild exercise was performed by the dry and wet-heat groups ($\dot{V}O_2 \approx 1.0$ L/min) while more strenuous work ($\dot{V}O_2 \approx 1.9$ L/min) was performed by the exercise group. Physiological responses to the work-heat test showed a lack of acclimatization in the exercise group. However, the short duration of the training program (6 days) must be considered when interpreting these authors' findings.

During the same year, Gisolfi (1) reported the observations of 6 young men after 100 min of level treadmill walking at 5.6 km/hr in dry heat (48.9°C db, 26.7°C wb) before physical training, after 4, 8 and 11 weeks of intensive interval training (30 min/day, 5 days/week), and after 8 days of heat acclimatization. The $\dot{V}O_2$max improved 11.5% after 4 weeks of training, 15% after 8 weeks of training and then remained unchanged (11 weeks). Utilizing the terminal T_{re}/performance time ratio as an index of heat tolerance, the percent of the total adjustment for heat acclimatization was 30, 57, and 65% after 4, 8 and 11 weeks of training, respectively.

In 1974, Nadel et al. (5) reported findings from 6 relatively unfit men who physically trained for 10 days (1 hr per day) at between 70-80% of their $\dot{V}O_2$ max in cool conditions (22°C db). After physical training, these men were heat acclimated for 10 consecutive days while exercising on a bicycle for 1 hour per day at 50% $\dot{V}O_2$ max (three subjects in a 45°C, dry environment and three subjects in a 36°C, humid environment). The physical training increased the mean $\dot{V}O_2$ max by 6.6 ml/kg • min while 10 days of heat acclimation was associated with significant reductions in HR and esophageal temperature (T_{es}). Results showed that physical training alone increased the responsiveness of the sweat glands (peripheral effect) without changing the point of zero central sweating drive. Heat acclimation lowered the point of zero central drive without altering the responsiveness of the sweat glands. Thus, peripheral mechanisms for heat dissipation appeared to be potentiated during training while central mechanisms became involved during acclimation. During physical training alone, an enhanced sweating responsiveness was achieved by an increase of 67% in the relation of average chest sweating rate (chest $\dot{m}_{sw}$)/T_{es}.

In 1975, Shvartz et al. (13) discussed the effects of 8 days (4 hrs/day) of (a) mild exercise in the heat (33.9°C db, 32.2°C wb), (b) mild exercise in cool conditions (21°C), and (c) resting in the heat on heat orthostatism (tilted to 70° head-up tilt). Each of these three groups had 6 Bantu men while exercise involved bench stepping (30.5 cm) at 12 steps/min ($\dot{V}O_2 \approx 0.9$-1.0 L/min). The mild training at 21°C resulted in minor improvements to work in the heat but better heat orthostatism than men who had only rested in the heat; the group that worked in the heat showed the greatest improvement in heat orthostatism. Once again, the effect of the low intensity and short duration of training must be questioned.

More recently, Pandolf et al. (6) evaluated the role of cardiorespiratory physical fitness in heat acclimatization, loss and reinduction of acclimatization. Twenty-four relatively fit soldiers (average $\dot{V}O_2$ max = 49.5 ml/kg • min) were heat acclimatized for 9 days while treadmill walking (4.8 km/hr) on the level for 110 min each day at 49°C, dry ambient. An individual's $\dot{V}O_2$ max was significantly related ($\underline{r}$ = -0.68, $P<0.01$) to the number of days for his T_{re} to plateau during acclimatization as illustrated in Figure 1. This correlation coefficient accounted for 46% of the variance between these two variables ($\dot{V}O_2$ max and T_{re} plateau day).

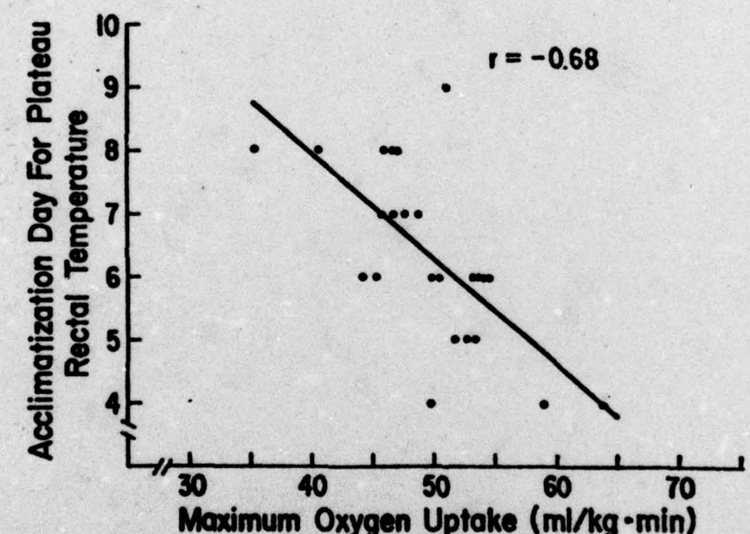

Fig. 1. Relationship between acclimatization day for a plateau in rectal temperature and the maximal oxygen uptake (ml/kg • min) of 24 soldiers (6).

Utilizing an experimental design very similar to that described earlier (5), Roberts et al. (9) evaluated the chest $\dot{m}_{sw}:T_{es}$ relation, and the arm blood flow (ABF) from a 10 cm segment of the forearm (measured by electrocapacitance plethysmography) as related to T_{es} (ABF:T_{es}) for 4 men and 4 women. The findings for the chest $\dot{m}_{sw}:T_{es}$ relation were similar to those described previously (5). Physical training increased $\dot{V}O_2$ max by 13% in the men and 11% in the women; training showed an increased ABF associated with a reduction in the T'_{es} (corrected) threshold for vasodilation with further reductions in the threshold during acclimation; no consistent changes in the slope of the ABF:T'_{es} relation were observed. The women showed similar trends compared to the men for chest

$\dot{m}_{sw}$:T_{es} relation, but sweating thresholds were always higher for the women at comparable testing periods. The ABF:T'_{es} slope relation showed no consistent differences between men and women at comparable testing periods, but the women had higher vasodilation thresholds than the men at all comparable stages. In studying the control of ABF, these authors concluded that they have demonstrated "a shift in the threshold for vasodilation, and by showing that exercise training produces an effect similar to heat acclimation".

A few months ago, Shvartz et al. (12) evaluated 26 unacclimatized young men ($\dot{V}O_2$ max range of 29-65 ml/kg • min) during work at 23°C (41 and 82 watt) and most men before and after 8 days of heat acclimatization (3 hrs at 41 watt, 39.4°C db, 30.3°C wb). Generally, the men with the higher $\dot{V}O_2$ max values showed better adjustment and those with the lower $\dot{V}O_2$ max values the poorest adjustment (HR and T_{re} but not necessarily sweat rate and $\dot{V}O_2$) at both 23°C and in the heat. The $\dot{V}O_2$ max correlated (r = -0.65) with T_{re} (3-hr value) in the heat, and indicated that $\dot{V}O_2$ max accounts for about 40% of the variability which determines the level of T_{re} during exercise in the heat. These authors concluded that "it is clear that fitness is related to heat tolerance".

Most recently, Henane et al. (4) studied the responses of 6 cross-country skiers ($\dot{V}O_2$ max = 66.5 ml/kg • min), 4 swimmers ($\dot{V}O_2$ max = 65.8 ml/kg • min), and 3 initially sedentary men ($\dot{V}O_2$ max = 40.9 ml/kg • min) during (a) passive heating (resting) with controlled hyperthermia, and during (b) sweating tests. After 3 months of intensive interval training, $\dot{V}O_2$ max for the sedentary men increased by 7.3 ml/kg • min (18%). The sweat output of the athletes was significantly higher and sweating onset shorter than the sedentary men. Although similar with regard to $\dot{V}O_2$ max, the skiers were superior to swimmers possibly because of their higher levels of body hyperthermia during training. After training, the sweat output of the sedentary men increased 28%, and was similar to the swimmers; sweat onset was shortened after training. When the sweat output of untrained, unacclimatized men was used as 100%, this computation was found to be 158% after heat acclimatization, 166% for swimmers and 190% for skiers. These authors stated that "improving $\dot{V}O_2$ max by endurance training enhances the sweating sensitivity and efficiency of heat dissipation" and further "a significant increase of about 15-20% of $\dot{V}O_2$ max appeared to be necessary for inducing heat acclimatization".

In order to achieve the most optimal benefits from physical training for increased heat tolerance or improved performance during heat acclimatization, the more recent literature shows the best gains from intensive interval or continuous training at a training intensity greater than 50% of $\dot{V}O_2$ max (1, 4, 5, 9). The compiled findings from Table 4 also show that the training program must exceed 1 week while Gisolfi (1) and Henane (4) show the best improvement in tolerance (heat) between 8 and 12 weeks of intensive training. It would seem that the training program should result in an increase of 15-20% of $\dot{V}O_2$ max to greatly improve tolerance (1, 4, 5). Improvement in work-heat tolerance from appropriate physical training appears to apply to both dry and wet heat.

Table 4. Major effects of endurance training or physical fitness on heat tolerance from recent experimental observations.

Heat tolerance or acclimatization	Performance Increase	Performance Decrease	Performance No Effect	References
<u>Training Related</u>				
Type of training				
- strenuous interval training	X			Gisolfi, 1973; Henane et al. 1977.
- mild continuous training			?	Shvartz et al., 1975.
- moderate continuous training			X	Shvartz et al., 1973.
- intensive continuous training	X			Nadel et al., 1974; Roberts et al., 1977.
Training intensity				
- < 50% $\dot{V}O_2$ max			?	Shvartz et al., 1975.
- > 50% $\dot{V}O_2$ max	X		?	Shvartz et al., 1973; Gisolfi, 1973; Nadel et al., 1974; Roberts et al., 1977; Henane et al., 1977.
Training duration				
- ≤ 1 week			X	Shvartz et al., 1973.
- > 1 week <4 weeks	X		?	Nadel et al., 1974; Shvartz et al., 1975; Roberts et al., 1977.
- ≥ 4 wks <8 wks	X			Gisolfi, 1973.
- ≥ 8 wks <12 wks	X			Gisolfi, 1973.
- ≥ 12 wks	X			Henane et al., 1977.
Fitness level				
- high $\dot{V}O_2$ max	X			Pandolf et al., 1977; Shvartz et al., 1977; Henane et al., 1977.
- low $\dot{V}O_2$ max		X	?	Pandolf et al., 1977; Shvartz et al., 1977; Henane et al., 1977.
Training effect				
- 0-10% increase in $\dot{V}O_2$ max			X	Shvartz et al., 1973; Shvartz et al., 1975.
- 10-20% increase in $\dot{V}O_2$ max	X			Gisolfi, 1973; Nadel et al., 1974; Roberts et al., 1977; Henane et al., 1977.
Type of subject				
- trained competitive athlete	X			Henane et al., 1977.
- untrained (at least initially)	X		?	Shvartz et al., 1973; Nadel 1974; Shvartz et al., 1975; Roberts et al., 1977.

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Utilization of proper physical training appears to produce about 50% of the total adjustment resulting from heat acclimatization. Two authors (6, 12) independently report that an individual's $\dot{V}O_2$ max accounts for between 42-46% of the variability determining the T_{re} level during exercise in the heat or heat acclimatization. Individuals with high $\dot{V}O_2$ max values and athletes whose endurance training programs cause high levels of body hyperthermia are at an advantage (4, 6, 12). Women have been reported to respond physiologically to physical training in a fashion similar to men. All of these recent research conclusions can be used in determining guidelines for the advanced preparation of armed forces entering tropical and desert areas of the world.

3.3 Retention of Heat Tolerance or Acclimatization

In 1967, Williams et al. (16) reported the percentage loss of acclimatization in winter after 1, 2, and 3 weeks in cool conditions. The calculated percentage losses for T_{re} and HR after these three time periods are presented in Table 5. Significant losses for both T_{re} and HR were observed after the 1st and 2nd weeks in cool conditions with 45% (T_{re}) and 92% (HR) losses after 3 weeks. In contrast using the same technique for calculating percentage loss, Pandolf et al. (6) showed no significant loss ($P > 0.05$) for both T_{re} and HR after 6, 12 and 18 days in cool conditions following 9 days of acclimatization (Table 5).

Table 5. Percentage loss of acclimatization in winter.

Weeks	1st	2nd	3rd
Rectal Temperature			
Williams et al., 1967 (16)	26%	35%	45%
Pandolf et al., 1977 (6)	13%*	18%*	4%*
	(six days)	(twelve days)	(eighteen days)
Heart Rate			
Williams et al., 1967 (16)	65%	87%	92%
Pandolf et al., 1977 (6)	23%*	20%*	29%*
	(six days)	(twelve days)	(eighteen days)

*Not significantly different from last (9th) day of acclimatization.

The earlier study (16) failed to quantify the cardiorespiratory physical fitness levels of their subjects and the role that fitness may play in the decay or loss of acclimatization. Pandolf et al. (6) conclude that "the physical fitness of our subjects is hypothesised as being the prime factor in their rapid acclimatisation, small decay and rapid reacclimatisation, even after 18 days".

4.0 Summary

Most authors agree that physical training in a cool environment improves tolerance to work in the heat and heat acclimatization but the extent or degree of improvement remains controversial. The major benefits of physical training appear

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to involve exposure durations (heat) of less than two hours. The best improvement in heat tolerance is associated with intensive interval or continuous training at a training intensity greater than 50% of the maximal oxygen uptake for 8 to 12 weeks; the maximal oxygen uptake should be increased 15-20%. Generally, individuals with high maximal oxygen uptake values (previously trained and endurance athletes) are at an advantage in the heat. Utilization of proper physical training appears to produce about 50% of the total adjustment resulting from heat acclimatization, while increased fitness is associated with greater retention of acclimatization in cool environments.

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Most authors agree that physical training in a cool environment improves tolerance to work in the heat and heat acclimatization but the extent or degree of improvement remains controversial. The major benefits of physical training appear to involve exposure durations (heat) of less than two hours. The best improvement in heat tolerance is associated with intensive interval or continuous training at a training intensity greater than 50% of the maximal oxygen uptake for 8 to 12 weeks; the maximal oxygen uptake should be increased 15-20%. Generally, individuals with high maximal oxygen uptake values (previously→(CONT over)

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trained and endurance athletes) are at an advantage in the heat. Utilization of proper physical training appears to produce about 50% of the total adjustment resulting from heat acclimatization, while increased fitness is associated with greater retention of acclimatization in cool environments.